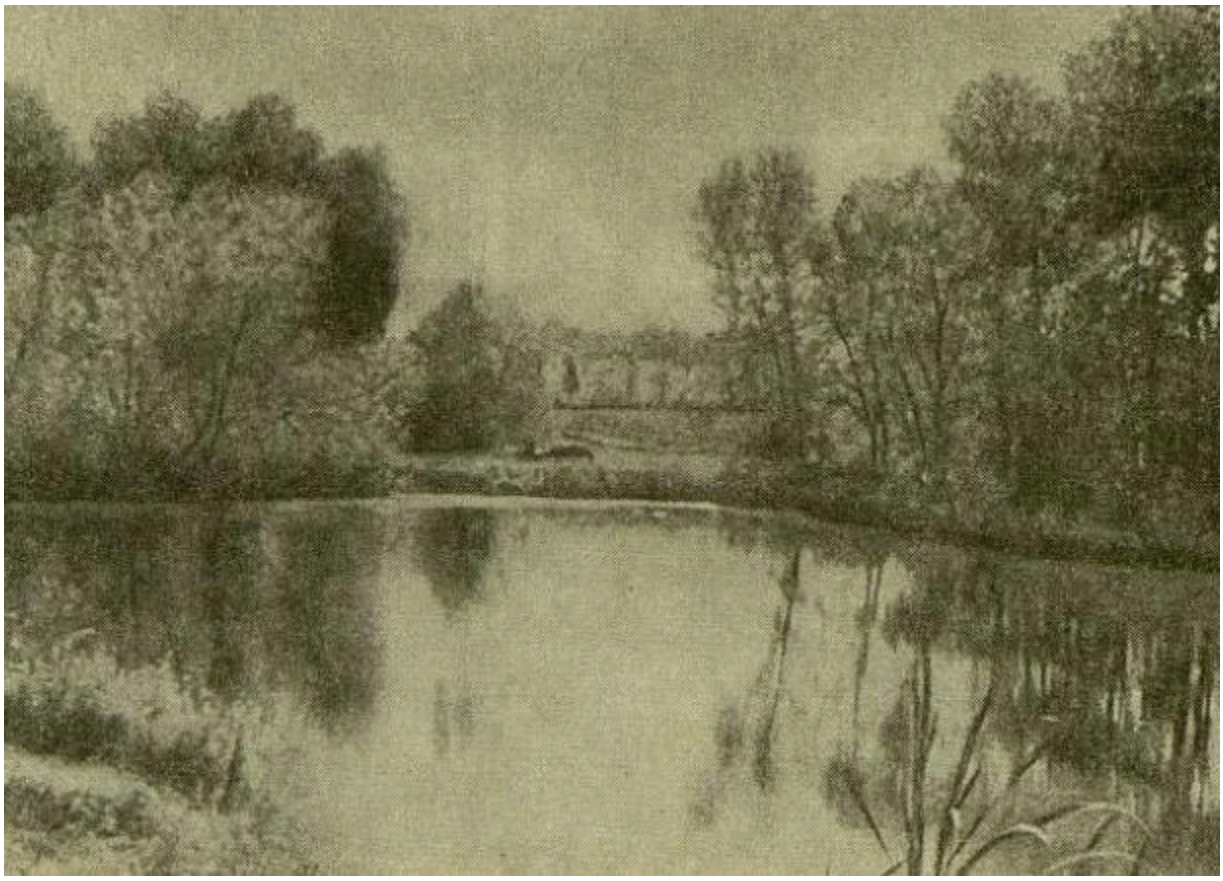
Sustainable Agriculture: How the World's First Model Evolved



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Sustainable Agriculture

Sustainable Agriculture, as a concept, entered the mainstream international development thinking in the late 1980s. It was at the initiative of the Food and Agriculture Organization (FAO) of the United Nations. The Report of the 94th Session of the Council of FAO, held in 1988, defines sustainable agriculture management as "the management and conservation of the natural resource base, and the orientation of technological change in such a manner as to ensure the attainment of continued satisfaction of human needs for present and future generations. Sustainable agriculture conserves land, water, and plant and animal genetic resources, and is environmentally non-degrading, technically appropriate, economically viable and socially acceptable.[1]

FAO's move to adopt sustainable agriculture as the new paradigm of agricultural development was not a spontaneous one. It happened against the backdrop of the failures as well as limitations of the Green Revolution – environmental degradation, depletion of soil fertility, overexploitation of groundwater setting stage for aridification and loss of biodiversity being the prominent ones. FAO's initiative was an attempt to fix these failures. Mainstream development shifted from a desperate focus on maximum production at all costs (which was the Green Revolution) to long-term production within ecological limits (sustainable agriculture).

In 1991, the FAO launched the Sustainable Agriculture and Rural Development (SARD) framework at the Den Bosch Conference, transforming the concept into actionable policy that balanced ecological stewardship with food security[2]. To transform the new paradigm into a set of field practices suitable for smallholder farming, the FAO launched its concept of Sustainable Crop Production Intensification (SCPI) in July 2011. It was followed by the publication of its landmark framework, Save and Grow: A policymaker's guide to the sustainable intensification of smallholder crop production[3].

Conceptually, sustainable intensification aims to produce more from the same area of land. At the same time it focuses on reducing negative environmental impacts and increasing contributions to natural capital and the flow of environmental services. FAO projected it as another paradigm shift in agricultural research and development. The focus areas of the "Save and Grow" framework were:

- Farming systems: These systems will be based on conservation agriculture practices, the use of good seed of high-yielding adapted varieties, integrated pest management, plant nutrition based on healthy soils, efficient water management, and the integration of crops, pastures, trees and livestock.

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[1] FAO. 1988. Report of the Council of FAO, Ninety-fourth Session, Rome, 15–26 November, 1988. CL 94/REP. Rome. https://www.fao.org/3/t0087e/T0087E00.htm#Contents,

[2] https://www.fao.org/4/w7541e/w7541e02.htm

[3] Save and grow: A policymaker's guide to the sustainable intensification of smallholder crop production, FAO. Rome 2011, https://www.fao.org/4/i2215e/i2215e.pdf

- Soil health: Agriculture must, literally, return to its roots by rediscovering the importance of healthy soil, drawing on natural sources of plant nutrition, and using mineral fertilizer wisely
- Crops and varieties: Farmers will require a diverse portfolio of genetically improved crop varieties that are suited to a range of agro-ecosystems and farming practices, and resilient to climate change.
- Water management: It will require smarter, precision technologies for irrigation and farming practices that use ecosystem approaches to conserve water.
- Plant protection: Pesticides kill pests, but also pests' natural enemies, and their overuse can harm farmers, consumers and the environment. The first line of defence is a healthy agro-ecosystem. The recommended measures include deployment of resistant varieties, conserving predators, crop rotations to suppress pathogens, and eliminating infected host plants.

In parallel with Sustainable Crop Production Intensification, FAO launched the concept of Climate-Smart Agriculture (CSA) in 2010. It aimed to support smallholder farmers with improved practices, innovations and techniques to adapt to and build resilience against climate change.

In 2013, FAO published Climate-Smart Agriculture Sourcebook[4]. This resource material contains eighteen modules. Some of those, such as Managing landscapes for Climate-smart agricultural systems;Water management; Soils and their management for Climate-smart agriculture; Conservation and sustainable use of genetic resources for food and agriculture; Climate-smart crop production system; Climate-smart Livestock and Climate-smart fisheries and aquaculture while addressing concerns related to adaptation and resilience to climate change also contribute to the broader goals of sustainable agriculture.

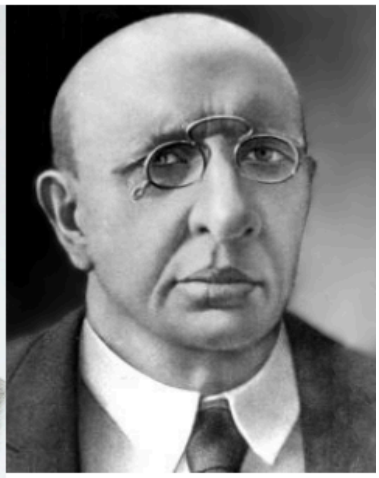
In subsequent years, FAO embraced agroecology in its vision for sustainable agriculture and food systems. It conducted a series of multi-stakeholder process with the goal of designing an agroecology framework adapted to local contexts. The output of this process, the 10 Elements of Agroecology framework, was launched at the Second FAO International Symposium on Agroecology held in April 2018. The Agroecology framework was approved by the 197 Members of FAO on 2-6 December 2019. It was followed by a 2020 FAO team peer-reviewed publication entitled "The 10 Elements of Agroecology: enabling transitions towards sustainable agriculture and food systems through visual narratives"[5]

The origin of Sustainable Agriculture

[4] CLIMATE-SMART AGRICULTURE Sourcebook, Food and Agriculture Organization of the United Nations, 2013,https://openknowledge.fao.org/server/api/core/bitstreams/b21f2087-f398-4718-8461-b92afc82e617/content

[5] Barrios, E., Gemmill-Herren, B., Bicksler, A., Siliprandi, E., Brathwaite, R., Moller, S., … Tittonell, P. (2020). The 10 Elements of Agroecology: enabling transitions towards sustainable agriculture and food systems through visual narratives. Ecosystems and People, 16(1), 230–247. https://doi.org/10.1080/26395916.2020.1808705

At the heart of the modern concept of sustainable agriculture lies concerns for the well being of future generations while utilizing natural resources (land, soil, water, forests, natural vegetation) to meet current needs for food, feed, fiber and other non-food uses. The focus is on optimization of the use of those resources that won't disrupt ecological balance and irreversibly compromise nature's capacity to provide vital ecosystem services. From that perspective, the origin of sustainable agriculture can be traced to the Russian Empire in the late nineteenth century. The conceptual framework of the world's first model of sustainable agriculture was laid out by three Russian/Soviet soil scientists and naturalists – Vasily Vasilievich Dokuchaev (1846–1903), Peter Andreevich Kostychev (1845–1895) and Vasily Robertovich Williams (1863–1939) . It rested on the following principles:



The landscape approach

V.V. Dokuchaev in his famous book "Our Steppes:Then and Now" published in wake of the 1891 famine laid out the scientific framework for the world's first model of sustainable agriculture. Dokuchaev's methodological approach to combat drought focused on diagnosing the root causes of drought. For this purpose, he conducted a thorough analysis of natural-climatic changes that occurred in Southern Russia's steppe region and various types of human interventions in the steppe ecosystem over a long period of time. The key findings of his analysis were:

1.. Russia's Black Earth Zone was undergoing a slow but inexorable process of desiccation. It was due to the following factors:
– The natural depressions of the steppes (in various physical forms, shapes and sizes) that once served as reservoirs for collecting run-off from melting snow and rain as well as sources for feeding hundreds of small steppe streams, were almost entirely destroyed. It happened because of development of a dense network of ravines, but primarily because of the near-total ploughing up of the steppe.
– The relatively impermeable geological formations (clayey loess, boulder clays, and the like)

that once blanketed the virgin steppes in an almost unbroken layer was washed away across vast areas of southern Russia. These formations retained water either on the surface or within their own mass. In their place loose sands, friable sandstones, fractured limestones, and similar materials were exposed. These materials were no longer capable of retaining atmospheric precipitation.

– Massive deforestation in Southern Russia by three- to fivefold or even more. The process encompassed forests found in the river floodplains or the purely steppe forests in the forest-steppe zone, forests grown on riverbanks and ravine slopes sometimes extending a long distance away from the river in the forest-steppe. These forests protected the land from erosion and wind, accumulated snow, retained soil moisture and also helped raise the groundwater table. These forests safeguarded springs, lakes, and rivers from siltation, and moderated spring floods by reducing their peak intensity while prolonging their duration.

– A vast portion of the steppe, and in many places most of it lost its natural cover: the pristine, typically very dense steppe vegetation and turf that once trapped large amounts of snow and water while shielding the soil from frost and wind.

– Meanwhile, cultivated fields—which in many areas now occupy up to 90% of the total land—had destroyed the granular soil structure characteristic of chernozem (black earth) most conducive to moisture retention, leaving the soil vulnerable to the wind and the erosive action of water.

2. Even assuming the volume of atmospheric precipitation reaching the ground remained unchanged, all these factors led to the following results:

- increased evaporation of steppe waters, and likely also increased nighttime cooling of the steppe;
- a reduction in soil moisture, and a lowering of the groundwater level;
- an extreme intensification of high-water periods (both spring-melt and rainfall-driven) in open steppe areas and rivers, accompanied by a reduction in their duration and a decrease in summer water reserves—both in the rivers and across steppe watersheds;
- the drying up and destruction of some springs and the silting over of others;
- vigorous and ever-increasing soil erosion washing fertile land from the steppe, along with the clogging of riverbeds, lakes, and various depressions with sand and other coarse sediments; and,
- finally, the intensified harmful impact of easterly and south-easterly winds—scorching winds that parch vegetation and dry up springs in summer, and cold winds that frequently destroy fruit trees and crops during winter and early spring.

3. The overall and inevitable result of all this was harsher winters and scorching, dry summers in southern Russia.

4. The impact of all these processes at work for centuries was amplified by more recent overtilling of soil including black soil causing gradual depletion of soil.

5. Most vigorous and decisive measures must be taken to restore the health of our agricultural system.

6. These measures must be holistic, strictly systematic, and consistent, much like nature itself; second, that they must be aimed primarily at eliminating—or at least mitigating—the very causes that have undermined our agriculture, depleted our soils and and rendered some of our rivers unfit for use; and third, that they must strive, as far as possible, to undo the damage already wrought—partly by the forces of nature and partly by human activity.

To incorporate these measures into an actionable framework for policy and physical interventions, V.V. Dokuchaev proposed a scientific organization of the territory. It took into account the territory's landscape morphogenetic structure; development and widespread planting of field-protective forest belts, implementation of anti-erosion measures; creation of a system of ponds and reservoirs for increasing soil moisture supply, widespread forest plantation; development of selection and genetics, adaptive seed production, and livestock farming. Given the comprehensive nature of this approach, its "cornerstone" was the protection and improvement of soils.[6]

Soil biology

P. A. Kostychev was among the first to demonstrate that soil formation is a biological process linked to the development of vegetation and microorganisms. Living organisms, having first settled (in the Precambrian) on abiotic rock, gradually transform it, accumulating essential nutrients, and after dying, enrich the upper horizons of the rock with nutrients and newly formed organic and mineral substances, which are used by subsequent generations of various biota. Thus, nutrients, water, air, and all the necessary conditions for the growth and development of higher plants gradually accumulate on the surface of the rock. This is how the main and most qualitatively important property of the soil is formed – fertility, which so strikingly distinguishes it from rock. He experimentally proved the role of microscopic fungi in humus formation. He established that the organic matter from the root systems of steppe plants—decomposing in the soil through the action of microorganisms—serves as the source of humus in black earth soils (chernozems)[7].

Kostychev demonstrated that the stability of soil fertility depends on the balance of organic processes – how plant residues decompose, how microorganisms function, and how plants compete with one another. His ideas led to the realization that for agriculture to be sustainable, it is necessary to manage not only soil chemistry but also soil biology. It can be done by preserving and stimulating its living component and strategically planning crop rotations that take into account the interactions between crops.

Soil agronomy

V.R. Williams established the leading role of biological factors in soil formation. On this basis, the scientist developed the theory of the small biological cycle of substances in the soil. He believed that the key to achieving high crop yields was the deliberate creation of a soil structure (fine-crumb) with the appropriate composition. For this purpose, Williams developed the grass-field farming system[8]. This system was based on growing a mixture of perennial leguminous and cereal grasses (such as alfalfa, sainfoin, and brome grass). Grown within a nine-field crop rotation, these crops used to occupy the land

[6] Профессор В.В. Докучаев. Наши Степи: Прежде и Теперь. С. Петербург, 1892.
[7] П. А. Костычев. Почвы чернозёмной области России, их происхождение, состав и свойства» (1886)
[8] Вильямс, В.Р. Травопольная система земледелия – М. Издательство Юрайт- 2017, -341 С.

for two to three years. Their root systems facilitated formation of stable soil aggregates and enriched the soil with humus, thereby enhancing soil fertility and structure.

In his works on soil science, V.R. Williams steadfastly adhered to the principle of V.V. Dokuchaev—the founder of genetic soil science. According to this principle, the basis of soil formation is the concept that soil properties develop from the parent material as a result of its alteration by soil processes driven by soil-forming factors[9].

V.R. Williams's grassfield farming system was a cropping system with a landscape approach and a range of agronomic practices: a) planting protective forest belts on watersheds, along the boundaries of crop rotation fields, on the slopes of ravines and gullies, and along the banks of rivers and lakes and around ponds and reservoirs, as well as afforestation and stabilization of sandy areas; b) proper organization of the territory, incorporating grass-arable field and forage crop rotations and the rational use of land resources; c) a sound system of soil cultivation and crop care, featuring the widespread use of bare fallow, autumn plowing, and stubble harrowing; d) a proper system for the application of organic and mineral fertilizers; e) sowing with selected seeds of high-yielding varieties adapted to local conditions; f) development of irrigation based on the use of local runoff waters through the construction of ponds and reservoirs.

We argue that the synthesis of V. V. Dokuchaev's landscape-centered concept of ecologically sustainable agriculture and the principles of soil biology and soil agronomy developed by P.A. Kostychev and V.R. Williams constitutes the world's first model of sustainable agriculture.

Sustainable agriculture: from concept to implementation

Frequent droughts in the Central Black Earth Zone of Russia prompted the search for actionable ways to transform the sustainable agriculture model from a concept to a reality. Indeed, historical chronicles indicate that prior to the 17th century, droughts occurred no more than eight times per century; by the 17th and 18th centuries, however, they were striking every six years. The drought of 1891 had particularly tragic consequences. It affected 28 governorates with a combined population of nearly 35 million people. Catastrophic crop failures caused severe food shortages and led to the dying out of entire villages. What caused this calamity? The dire necessity to find an answer to this question prompted the Imperial Government to initiate action.

The first step in this direction was taken on 22 May 1892. The Department of Forestry and State Property formed a "Special Expedition for Testing and Evaluating Various Methods and Techniques of Forestry and Water Management in the Steppes of Russia". The expedition team was headed by Vasily V. Dokuchaev, Professor of mineralogy and geology of St. Petersburg University (shown in the photo below).

[9] Вильямс В.Р. Собрание сочинений. Т. 1-12. – М.: Сельхозгиз, 1948-1953. т. 5. – 624 с.

Other members of the Team were prominent soil scientists of that time – Konstantin D. Glinka, Nikolai M. Sibirtsev, Konrad E. Sobenevsky, V.N. Deich, Pavel V. Ototsky, Anatoly A. Silantyev, Gavrill I. Tanfilyev, Nikolai P. Adamov, and others. The Expedition was tasked with: 1) a comprehensive study of the natural conditions shaping steppe climate, soil, and vegetation; and 2) the identification of methods to combat periodic droughts.

The expedition started working beginning on 8 June 1892. The creation of the Special Expedition was followed up with the founding of another organization in 1894 – the Bureau of Applied Botany. It was the predecessor of the world's first plant Gene Bank, the All Union Institute of Plant Industry (widely known as VIR) headed by N.I Vavilov. Thus in the early nineteenth century two important organizations were established in Russia – the Special Expedition for Testing and Evaluating Various Methods of Forest and Water Management in the Russian Steppes (1892) and the Bureau of Applied Botany (1894) that set the stage for testing and implementation of the world's first model of sustainable agriculture.

Based on the overall objectives, the activities of the Special Expedition were divided into scientific and practical work. The scientific work involved organizing detailed meteorological observations, studying the soil and compiling soil maps, and investigating steppe flora and fauna. Practical work focused on developing methods for managing forestry and water resources. It included planting forests in the steppe for various agricultural purposes, such as protective shelterbelts and moisture-harvesting plantations. With regard to water management, the initial work included the construction of ponds. Ponds were seen as the simplest means of conserving water that nature bestows on the steppes in the

form of snow and rainwater. Wattle fences, the plowing of snow using wide wooden plows, and other methods were also employed "to conserve snow and snowmelt."

The expedition worked at three sites. One of them—the Khrenovskoy site, located on the Volga-Don watershed — was in the Bobrov Uyezd of Voronezh Governorate. The Khrenovoye study area comprised three sites: Khrenovskoy Bor—a coniferous forest tract with an adjoining strip of "perfectly flat" steppe extending over 20 km. There was Shipov Les—a deciduous forest tract with steppe terrain deeply dissected by ravines. The third was the state-owned "Kamennaya Step" (Stone Steppe) tract—a treeless watershed area of dry feather-grass steppe.

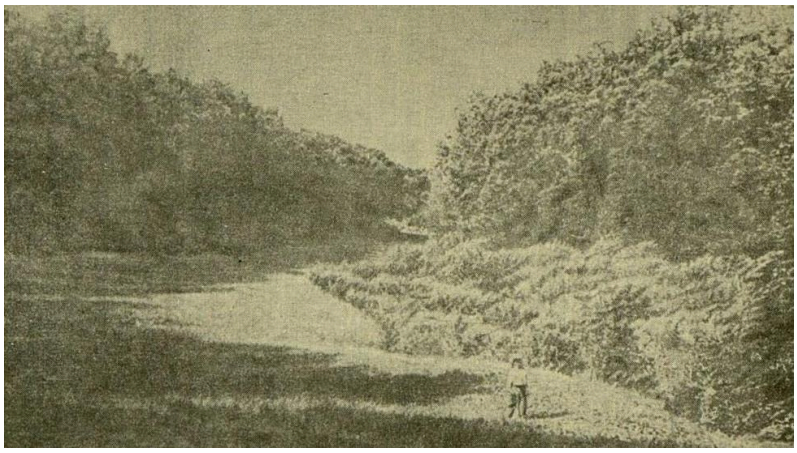
Research on the impact of forest tracts on adjacent steppes was launched at the Khrenovskoye and Shipovskoye field stations. All experimental work on testing forest-reclamation measures was concentrated in the Kamennaya Steppe. The Kamennaya Steppe research station became the most significant in the scope and content of experimental work. It was the only site where all protective forest plantations were established exactly as prescribed by the afforestation plan drawn up in 1892 by the noted forestry scientist O.I. Kovalyov.

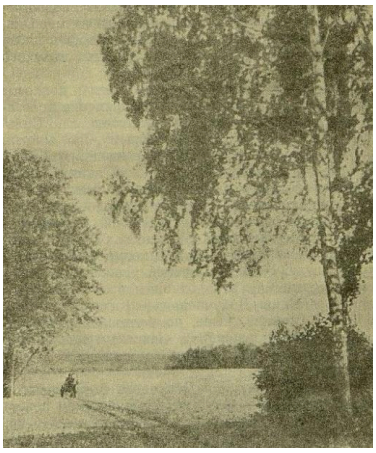
It was on this site that the objectives set forth in the expedition's experimental programme were most fully realized. V.V. Dokuchaev himself briefly summarized those objectives as follows: "…The aim of the expedition is to improve natural agricultural conditions by regulating water management in Russia's steppe zone through various afforestation and water-supply works." V.V. Dokuchaev ranked the "planting of forests for various purposes serving agriculture" as the key element in the efforts of steppe restoration. Belt-like plantings were intended to protect crops from winds, storms, and hot dry winds. They were also intended to facilitate the regulation of snow cover and the accumulation of snowdrifts and ridges in appropriate locations; and to stabilize slopes and ravines.

During the expedition's period of activity (1892–1899), 58 protective forest plantations were established covering an area of 103 hectares. After the expedition was closed in 1899[10], a forestry station was established in the Kamennaya Steppe. It was headed by G.F. Morozov, a follower of Dokuchaev and a noted Russian forestry scientist. Over the nine years of the forestry station's operations, G.F. Morozov and N.A. Mikhailov, his successor after three years, established the most valuable shelterbelts. For the first time in the history of field- protective afforestation in the arid steppe, widespread use of the tree species "Oak" began. It was included in the shelterbelts originally planted by V.V. Dokuchaev's expedition. It was also included in 35 new plantations covering an area of 95 hectares. G.F. Morozov favoured tree-shrub and pure-shrub species mixtures, sometimes combining them with a tree-and-understory arrangement. N.A. Mikhailov continued testing designs and cycles for mixing tree species. In 1903, he established the most significant shelterbelt, No. 40. Thanks to the proper selection of tree species, all the "Morozov" and "Mikhailov" shelterbelts have been well preserved and are

[10] Because of illness, V.V. Dokuchaev retreated from active work. He passed away in 1903 at the age of 57.

distinguished by their excellent condition and high productivity. Funding for the forestry station was discontinued in January 1908. The shelterbelts were left without maintenance or protection.[11]





(Forest strips planted by V.V. Dokuchaev, 1946 photo)

Kamenno-Stepnaya Experimental Station

Three years later the forestry station was upgraded. On 16 June 1911 the V.V. Dokuchaev Kamenno-Stepnaya experimental station (Каменно-Степная опытная станция им. В.В. Докучаева) was established. The overall objective of the experimental station was to carry forward the tasks set forth in the 1892 Special Expedition as described above. It also became the field laboratory for testing the validity of the first model of sustainable agriculture, as outlined above. An area of 1,214 hectares was allocated to the experimental station. It comprised shelterbelts, plots of land lying fallow for long periods, and a tract of open steppe for conducting field experiments.

However, practical work on planting new forest strips and maintaining existing ones began only in 1925 after the establishment of a forestry department within the station's structure. Between 1927 and 1936, a total of only 12 shelterbelts were established. Agroforestry activities intensified in 1937; new plantings were established on lands annexed to the station, bordering fields ranging from 60 to 120 hectares in size. The belts were no more than 16–20 meters wide and, unlike pre-revolutionary ones, lacked shrubby margins. In subsequent years, scientists developed and implemented new methods for growing tree species and new designs for accommodating companion species in shelterbelts to ensure faster growth of tree saplings.

Grass-field crop rotations

[11] Турусов В.И., Лепехин А.А. Защитное лесоразведение в Каменной Степи . Достижения науки и техники АПК. 2016. Т.30. №7. С. 56-58.

While the first plantings of field-protective forest strips in the Kamennaya Steppe were done in 1894, experiments on grass-field crop rotations, the other component of sustainable agriculture, started after the establishment of the Kamenno-Stepnaya Experimental Station in 1911. The main objective of the study was to examine the comparative productivity of three-field and four-field crop rotations (the latter including one field of row crops) located in the steppe and among shelterbelts. The experiments demonstrated that four-field crop rotations were the most productive; crop yields in these rotations were higher. In 1914, the construction of a new weather station in the open steppe was completed. It was intended to provide microclimate data for comparison with information obtained by the weather station located amidst the shelterbelts.

Experiments with ten-field crop rotations, as suggested by V.R. Williams were set up near these weather stations. The experiments were set up in two replications. Plots of fallow lands of equal size were left between the experimental fields as control. But those experiments were aborted with the outbreak of the civil war. Later, in the 1930s the experiments on grassfield crop rotations renewed under the direct guidance of V.R. Williams. There were initial setbacks linked with the failure of growing grasses following winter crops because of faulty agrotechnical practices.[12]

In November 1935, Williams drafted a special set of instructions, standardizing agronomic practices for growing grasses. Using the standardized procedures, the staff at the experimental station succeeded in growing grasses following the winter wheat crop. It effectively restored the soil structure, and produced abundant forage yields. In subsequent years, the positive effect of grassfield crop rotations on crop yields became evident and consistent.

From 1934 to 1936, prior to the introduction of proper crop rotation systems, the average yield of winter grain crops was 1.33 tonnes per hectare. During the subsequent three-year period, as the grass-field farming system was just beginning to be implemented, this figure rose to 1.88 tonnes per hectare. Over the same period, the yield of spring grains increased from 0.97 to 1.36 tonnes per hectare. The effect was striking, even though 1938 and 1939 were drought years.[13]

Encouraged by these results, the research staff at the experimental station took steps to transfer the new technology to the agricultural farms. They helped the nearest collective farm—the V. V. Dokuchaev Collective Farm—switching to the new system in 1936. By 1940, having adopted the grassfield system, the farm became one of the region's leading agricultural enterprises. Recognizing this achievement, the Government awarded the head of this collective farm , P. Y. Belousov with the Order of Lenin. In 1938, the grassfield farming system was introduced in another nearby collective farm – "Novy Pakhar (in English New Farmer)." To assist the collective farm, the station planted shelterbelts in its fields. The transition to the new farming system sparked enthusiasm among the collective farmers; many of them

[12] О.А. Абанина, Н.С. Беспалова, С.Ю. Кивва. Краткий Обзор Деятельности Каменно-Степной Опытной Станции, Созданной на базе Докучаевской Экспедиции. International Journal of Humanities and Natural Sciences, Vol. 8-2, (83), 2023.
[13] Игорь Аркадьевич Крупеников, Вильямс, https://sv-scena.ru/Buki/Viljjyams.48.html

began—entirely of their own initiative—to establish tree nurseries on their personal garden plots (citation 7)

As a result of the introduction of the grassfield farming system, crop yields in the Kamennya Steppe doubled by 1945 compared to what was achieved during the 1934–1936 period. The data from a long-term field trial set up by V. R. Williams convincingly demonstrated that the yield of spring wheat was highest, 3.05 tonnes/ha, when all elements of the sustainable agriculture model were applied – protective forest belts + perennial grasses as preceding crops in the crop rotations + the use of fertilizer (shown in the Table below)[14].

Yield of spring wheat (t/ha)

	In the open steppe		Inside the forest belt	
	Without fertilizer	With fertilizer	Without fertilizer	With fertilizer
Following perennial grasses	1.81	2.12	2.53	3.05
Following other preceding crops	1.68	1.89	2.06	2.24
Difference	0.13	0.23	0.47	0.81

Water management

For water management, the Expedition Team considered measures based on the recommendations with regard to water management made by V.V. Dokuchaev in his book “Our Steppes: Then and Now”:

River regulation:

Major rivers - Volga, Dnieper, Don, Dniester, Kama, Oka

- Narrow the river's active cross-section where possible, straighten its course where necessary, construct additional reservoirs, etc.
- Reduce spring floods
- Prevent coarse sediment—such as gravel, sand, etc.—from entering the river valley in general, and the river channel in particular; to this end, it is necessary to: a) plant trees along the immediate riverbanks, especially on adjacent sandy areas and crumbling upland banks; b) block the mouths of ravines opening into the river valleys using wattle fences or other means, wherever possible.
- Eliminate shoals and snags.

Smaller rivers and the non-navigable headwaters of large rivers:

[14] Проф. В. С. Дмитриев. В. В. Докучаев и подъем степного земледелия. статья к книге В.В. Докучаева - Наши Степи: Прежде и Теперь. Государственное Издательство Сельскохозяйственной литературы, Москва, 1953.

- Treat the banks and ravine mouths in the same manner as for large rivers.
- Dam the riverbeds with permanent structures in order to: a) regulate—at least partially—the flow of spring waters and heavy rainfall runoff; b) harness the motive power of the water for various needs; c) Irrigate—using these waters as well as the spring waters of large rivers trapped in areas situated at relatively high elevations within distinct artificial basins—such as old and new floodplains—parts of river valleys covered by deposits from adjacent ravines, and the lower thirds of gentle river slopes.

Regulation of ravines and gullies.

Depending on the nature of the ravines and gullies—their shape, depth, and, above all, the geological structure and groundwater levels of the surrounding steppe—it is necessary to:

- Dam some of them with a series of wattle fences and live hedges to halt further erosion of their beds and banks and to transform them into meadows.
- Dam off other ravines and gullies—especially at their flat upper reaches where they emerge onto the steppe (an area often characterized by natural depressions)—using dams arranged in multiple rows in places to create ponds; the aim is to retain snowmelt and rainwater and to irrigate the lower-lying slopes and gully bottoms.
- Plant trees around both ravines and gullies—particularly in their upper reaches, on steep slopes, at spring outlets, and around catchment basins.
- Clear out and generally improve the condition of all spring outlets.
- Prohibit the plowing of steep ravine slopes.

Regulation of water resources in open steppes and in watershed areas.

To better utilize snowmelt and rainwater; to mitigate spring and other floods—whether on the steppe or along rivers; to increase soil moisture and raise the groundwater table; to provide irrigation water; and; finally, to increase atmospheric humidity and dew formation, it is necessary to:

- Establish systems of ponds across steppe watersheds, primarily along natural depressions and hollows—and especially along the natural runoff paths of spring meltwater and rainwater across the steppe, and plant trees along the pond banks.
- In other areas of open steppe, plant rows of hedges accompanied by small—but, where possible, long—embankments, similar to those formed when digging ordinary ditches. This will undoubtedly facilitate snow accumulation on the site, as well as the retention and better utilization of spring meltwater and rainwater.
- Areas of open steppe—specifically sands, hillocks, and any tracts generally unsuitable for cultivation, especially those exposed to strong winds—should be planted with continuous forest.
- To test various types of artesian and other wells on steppe lands of varying elevations; the undoubted success of some of these would yield a powerful new source of irrigation—one that has hitherto been completely lost to agriculture.

Establishment of standards determining the relative proportions of arable land, meadows, forests, and water bodies

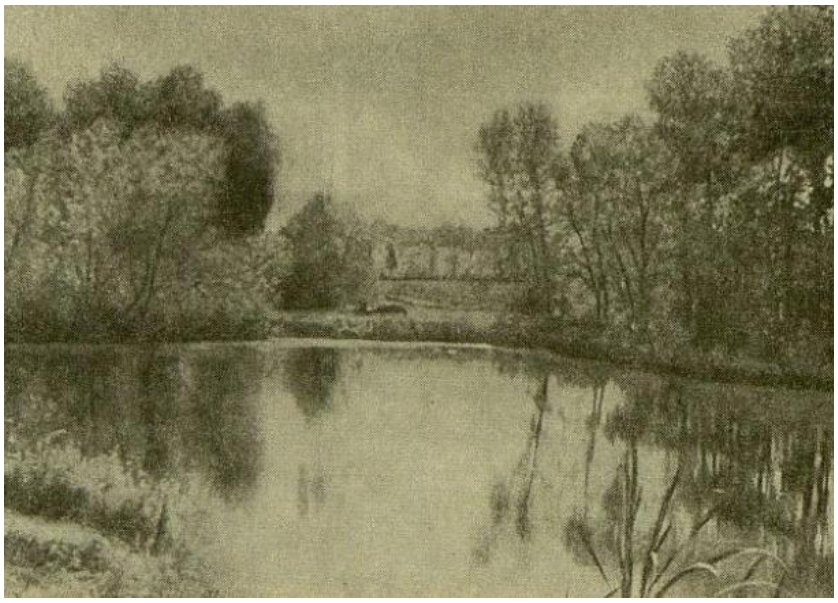
such standards must, of course, be adapted to local climatic, subsoil, and soil conditions, as well as to the nature of the prevailing agricultural crops, etc.

Final determination of soil cultivation methods most favorable for the optimal use of moisture, and better adaptation of crop varieties to local soil and climatic conditions.

Pond construction principles

The construction of ponds must take into account: a) the terrain; b) the nature of the groundwater (its levels, composition, volume, and general dynamics); and c) the geological and d) meteorological characteristics of the area. Regarding the last point, it should be noted that without knowledge of precipitation levels and evaporation rates, one could easily find the ponds left without water.
In essence, the same precautions regarding a thorough study of local soils must be observed when establishing any form of artificial irrigation. However, special attention must be paid to the composition of the irrigation water, the soil of the irrigated areas, and the climate.

During the period of the expedition's work (1892–1898), six new ponds were constructed and nine old ones restored; an irrigation tract of 25 hectares was established, featuring a main irrigation canal approximately 2 km long and a network of secondary canals equipped with sluices and furrows laid out along contours and slopes; and measures were implemented to stabilize ravines[15].



[15] Каминин И.В., Винокурова,И.К. Прошлое и настоящее Каменной Степи. М.: Россельхозиздат, 1970 22 с.

(One of the ponds constructed by V.V. Dokuchaev, photo taken in 1946)

Selection and breeding: the Kamenno-Stepnaya branch of the Bureau of Applied Botany

Besides planting of protective forest belts, construction of ponds and water reservoirs, standardizing soil-protective and moisture-conserving agronomic practices, the experimental plan for combating drought also had a focus on selecting crop varieties well adapted to local soil and climatic conditions. In 1894, the Scientific Committee of the Ministry of Agriculture and State Property created the Bureau of Applied Botany (BAB). It was subsequently reorganized (in 1930) into the All-Union Institute of Plant Industry (Всесоюзный институт растениеводства, ВИР).

Following the establishment of the Kamenno-Stepnaya Experimental Station in 1911, a Steppe Division of the Bureau of Applied Botany was opened on the Kamennaya Steppe, not far from the Experimental Station. The initiative was led by R.E. Regel, the head of the BAB (1904–1920). The division's mission was to conduct research on the morphobiology of steppe and wild vegetation and to select drought-resistant crops and varieties suitable for cultivation under steppe conditions.

The choice of Kamennaya Steppe was prompted by the absence of flowing water, the dry climate, and the prevalence of southeasterly winds. This open, elevated tract—situated on the watershed between the Bityug and Khoper rivers—was well-suited for evaluating the drought resistance of plants.

The station's scientific objectives focused on testing and evaluating varieties, both local and exotic, and lines (selections from breeding populations and old varieties), as well as hybrid populations of various agricultural crops for their adaptability to local natural and climatic conditions. The best performing lines were selected, multiplied and subsequently used for research and production purposes. Considerable attention was devoted to the botanical study of not only cultivated crops but also steppe and weed vegetation, as well as the changes occurring in the plant cover under the influence of mowing, livestock grazing, and plowing. Proximity to the protective forest belts—established by V.V. Dokuchaev's expedition and the forestry service—served as an additional basis for conducting research. Weed vegetation was also studied, including a large collection of wild oats. The research results obtained at the station during those years formed the basis for the scientific activities of the Department of Applied Botany. These results helped to understand the varieties of Russian wheat and publish the "Wheat Guide," study barley varieties, establish the genetic relationship between cultivated and wild oats, and systematically analyze sunflowers

In total, between 1911 and 1916, 8,448 samples of various wheat forms, 10,826 barley accessions, and 3,388 oat accessions were sown and studied at the station. Samples of millet and certain oilseed crops were also tested. The material under study was evaluated for economically important traits. The scope of the work of the Steppe Division of the BAB was expanded after reorganization of BAB into the All-Union Institute of Plant Industry (VIR) led by N. I. Vavilov. A key event that launched the breeding

work was the transfer, in the autumn of 1923, of the so-called "geographic plantings" to Kamennaya Steppe —a series of experimental sowings conducted at various locations across the country on the initiative of N. I. Vavilov. These plantings served as the foundation for the morphophysiological and agrobiological study of global cultivated plant collections and for the development of source material for practical breeding.

Starting in 1924, work on developing new varieties began under the leadership of N.I. Vavilov and L.I. Govorov, head of the Grain Legume Department at VIR (who simultaneously served as head of the Steppe Division from 1925 to 1933. Initial breeding material was developed from collection samples. Breeding strategies, schemes, and methods were formulated. The further development of this breeding programme led to the establishment of a breeding station at the Kamennaya Steppe in 1934, which operated until 1946. Breeders worked with extensive collections of agricultural crops: wheat (winter and spring), barley, oats, millet, rye, corn, sunflower, rapeseed, grain legumes (peas, beans, chickpeas, and others), and many others.

In the context of the drought of 1946, the government took the decision to merge the VIR-operated breeding station with the Kamenno-Stepnaya Experimental Station and create the V.V. Dokuchaev Agricultural Institute for the Central Blackearth Zone. Breeding research carried out between 1931 and 1946 resulted in the development of more than 40 varieties of various agricultural crops. Among the spring wheat varieties developed were: Gordeiforme 1, Gordeiforme 4, Lutescens 60, Lutescens G45, Dymchataya 34, Erythrospermum 108, Stepnaya 70, and Gostianum 15. However, only one of them—Gordeiforme 4—was cultivated on a commercial scale. The major winter wheat varieties developed were Gostianum 237 and Stepnaya 135. In this work, accessions from VIR's global plant genetic resources collection served as valuable starting material for the development of new varieties[16].[17]

1946 drought

The first big environmental test for the effectiveness of the first model of sustainable agriculture implemented in the Kamennaya Steppe came in 1946. A severe drought struck a vast region of the country. It affected more than 50 percent of the Soviet Union's cultivated areas – Ukraine, the North Caucasus, the Black Earth region, the Volga region, south-Western Siberia, and Kazakhstan. The famine that followed in 1947 claimed the lives of more than half a million people. Amid this natural disaster, the harvest at the Kamennaya Steppe Experimental Station was half the 1943–1945 average (1.5–1.6 tonnes per hectare), yet it remained virtually the same as in ordinary years. The drought's adverse impact was significantly mitigated by the use of a grassfield farming system combined with the protective forest

[16] В. И. Турусов, Б.А. Дорохов. ВИР в истории Каменной Степи. DOI 10.24411/2076-8176-2020-13003. https://docs.yandex.ru/docs/view?

[17] Малокостова Е.И., Беспалова Н.С., Абанина О.А. История селекции сельскохозяйственных культур в Каменной Степи. Международный научный журнал «ВЕСТНИК НАУКИ» № 6 (99) Том 2. ИЮНЬ 2026 г.

belts. In contrast, crop yields on farms surrounding the experimental station were three to four times lower.[18]

This event drew the country's spotlight on the Kamenno-Stepnaya model of sustainable agriculture centered on protective forest belts, grassfield cropping systems and water management. It became the precursor to the Great Plan for the Transformation of Nature adopted by the Soviet Government in 1948.

The Great Plan was, in essence, a scaling up of the Kammeno-Stepnaya model of sustainable agriculture on a large geographical scale. The project, spanning the period from 1949 to 1965, envisaged the creation of eight major protective forest belts (shelterbelts) in steppe and forest-steppe regions. The total length of these shelterbelts was 5,320 km that covered areas along the floodplains and watersheds of major rivers – the Volga, Dnieper, Don, Ural, and Seversky Donets. The project had a second, unofficial name the "Stalin Plan for the Transformation of Nature." Shelterbelts covering 117,900 hectares were intended to protect the 120 million hectares from hot, dry winds blowing from Central Asia. Over a 15-year period, the plan called for the creation of agroforestry complexes at smaller regional and local levels through the planting of 10–12 million hectares of forest . The project also envisaged the construction of 44,000 water bodies to form an integrated irrigation system.[19]

The details of the project are discussed in the book "The Great Plan for Transformation of Nature: A landmark environmental engineering project (1948–1965)"[20]. The plan designed for implementation over a period of fifteen years was abruptly terminated in 1953. The new leader of the country, Nikita Sergeievich Khrushchev, who assumed power following the death of the longtime leader Joseph Stalin did it mainly on political considerations. Forest-reclamation projects were halted, reclamation research stations were closed, and the soil-protecting grassland farming system was dismantled. His main goal was to end the Stalin era in all its forms, banish the great leader from public life, tarnish his image and set the stage for realization of his own big dreams and grand designs, no matter what it would cost to the country. But the Kammeno-Stepnaya model of sustainable agriculture survived. Ongoing research activities were expanded at the parent institution. It was renamed as "the V.V. Dokuchaev Agricultural Research Institute for the Central Black Earth Zone" in 1956.

The significant expansion of agroforestry amelioration research since the 1950s made it possible not only to continue the search for optimal methods of establishing forest plantations but also to initiate a comprehensive study of the impact of shelterbelts on crop yields, microclimate, soil fertility, and other factors. Research focused on improving methods of growing tree species in forest belts by radically

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[18] Виктор Турусов. Докучаевские бастионы в действии. К 75-летию Государственного плана преобразования природы.
https://vrnikc.ru/news/dokuchaevskie-bastiony-v-dejstvii-k-75-letiyu-gosudarstvennogo-plana-preobrazovaniya-prirody/

[19] *Турусов В.И., Коновалова Е.Я.* Реализация идей В.В. Докучаева в Государственном плане преобразования природы// Плодородие. – 2024. – №3. – С. 92-95. DOI: 10.24412/1994-8603-2024-3138-92-95. EDN: TRSTFS.

[20] Indrajit Roy. 2026. The Great Plan for transformation of Nature: A landmark environmental engineering project (1948–1953) https://archive.org/details/the-great-plan-for-transformation-of-nature

altering the species composition and their arrangement. Increasing the inter-row spacing from 1.06–1.4 m to 2.5–3 m made it possible to significantly reduce the costs of establishing and maintaining forest plantations. A new diagonal-cluster method was developed for planting forest tree seedlings. It enabled full mechanization of the agrotechnical maintenance of young stands and ensured their faster growth. A new method of plantings using large-sized stock was developed. It was capable of exerting a beneficial ameliorative effect on adjacent fields as early as the year of planting. By the fifth year, the cumulative ameliorative gain almost fully recouped the costs of establishment. In contrast, it took 9–10 years for the shelterbelts planted using seedlings of the same species to reach this point.

The enduring legacy of the Kamenno-Stepnaya model of sustainable agriculture

In 2017, the Kamenno-Stepnaya Agricultural Research Institute was formally known as the Federal State-funded Scientific Institution "V. V. Dokuchaev Agricultural Research Institute of the Central Black Earth Zone". The institute organized a scientific conference on 27–28 June 2017. The event was dedicated to the celebration of the 125th anniversary of the "Special Expedition of the Forestry Department for Testing and Evaluating Various Methods and Techniques of Forestry and Water Management in the Steppes of Southern Russia." It was an opportunity for the participants to put a historical context and take a retrospective view of how the world's first model of sustainable agriculture laid out in the works of Vasily V. Dokuchaev, Peter A. Kostychev, and Vasily R. Williams took shape, matured over the years and delivered expected benefits.

Based on long-term field trial data, the Table[21] below shows the effect of the sustainable agriculture model (the system of the Dokuchaev agroforestry-reclamation complex) on selected soil fertility parameters and grain yield. Averaged over 50 years, grain yield in the system of Dokuchaev complex exceeded the yield from the crops grown outside the system of shelterbelts by 0.59 t/ha. The effect on prevention of soil erosion was particularly prominent; annual soil loss was 0.5-1.0 m^3/ha inside the Dokuchaev complex compared to outside the system of shelterbelts. The effectiveness of the sustainable model was particularly evident during the years of drought.

Research shows that protective forest belts significantly improve the microclimate. Data spanning 130 years indicate that fields protected by forest belts experience optimized seasonal groundwater levels, a 30–35% reduction in wind speed, and a 25–30% increase in snow accumulation—factors that prevent deep soil freezing and rapid melting of snow.[22]

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[21] Турусов В.И. 2017. Научное наследие В.В. Докучаева и его роль в развитии земледелия ДОКУЧАЕВСКОЕ НАСЛЕДИЕ И РАЗВИТИЕ НАУЧНОГО ЗЕМЛЕДЕЛИЯ В РОССИИ: Сборник научных докладов Всероссийской научно-практической конференции, посвященной 125-летию организации «Особой экспедиции лесного департамента по испытанию и учету различных способов и приемов лесного и водного хозяйства в степях южной России, 27 – 28 июня 2017 года. Каменная Степь 2017

[22] Павловский Е.С. Докучаев и современная агролесомелиорация / Е.С. Павловский // Сб. Каменная степь – 100 лет спустя, 1992. – С. 32-41.

	Relative humidity, % over 30 years		Available moisture reserves, mm (May 2012)		Humus, % over 25 years	Soil loss, m³/ha (per year)	Grain yield, t/ha over 50 years
	In June	In July	0-20 cm	0-50 cm			
In the system of the Dokuchaev agroforestry-reclamation complex	34 - 35	32 - 34	1 - 12	35 - 42	6.5 - 7.0	0.5 - 1.0	3.26
Outside the system of shelterbelts	32	28	0.00	4.7	6.0	4.9 - 7.8	2.67

The shelterbelts of the Kamennaya Steppe have a positive impact on protecting the soil against erosion. Studies show that runoff decreases by an average of 55–60% when the catchment area has 6% forest cover, while erosion processes subside and wind speed decreases. Due to reduced physical evaporation in protected areas, the evaporation rate decreases by an average of 15–17%, and moisture savings amount to 40–50 mm. Field-protecting forest belts help reduce surface runoff while enhancing groundwater and subsurface flow, thereby significantly improving the soil water regime[23].

The scaling up of the Kamenno-Stepnaya model of sustainable agriculture, which was the Stalin Plan for the Transformation of Nature could be equally successful if it was not rolled back in 1954. This mistake was evaluated as follows:

Perhaps, had the USSR succeeded in implementing Stalin's Plan for the Transformation of Nature, it might have been possible to avoid many adverse natural phenomena—specifically the droughts and dust storms that struck the southern regions of the European part of the country in 1960, 1963, 1969, 1972, 1974, 1984, 2010, and 2015, causing significant damage to agriculture. Strong spring winds, with gusts reaching 28–30 m/s, caused the destruction of crops across vast areas; a 2–5 cm soil layer was completely lost, with soil losses reaching 20–50 t/ha and humus losses up to 5–6 t/ha[24].

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[23] *Турусов В.И., Лепёхин А.А., Чеканышкин А.С.* Опыт лесной мелиорации степных ландшафтов (К 125-летию «Особой экспедиции…» В.В. Докучаева): Монография / В.И. Турусов, А.А. Лепёхин, А.С. Че-канышкин. – Воронеж: Истоки, 2017. – 228

[24] Кулик К.Н. 2017. К 70-летию постановления «О плане полезащитных лесонасаждений, внедрения

Discussion

Our discussion will focus on how the ideas and principles of the world's first model of sustainable agriculture – laid out by V.V. Dokuchaev, P.A. Kostychev, and V.R. Williams – were adopted and reframed in the modern concept of sustainable agriculture.

The concept of soil health

In 2008, the Food and Agriculture Organization (FAO) of the United Nations came up with this definition of soil health: It is the capacity of soil to function as a living system, with ecosystem and land use boundaries, to sustain plant and animal productivity, maintain or enhance water and air quality, and promote plant and animal health. Healthy soils maintain a diverse community of soil organisms that help to control plant disease, insect and weed pests, form beneficial symbiotic associations with plant roots; recycle essential plant nutrients; improve soil structure with positive repercussions for soil water and nutrient holding capacity, and ultimately improve crop production"[25].

That soil is a living system was first highlighted by Russian scientists in the late nineteenth century. The first scientific definition of soil was provided by V.V. Dokuchaev, who defined soil as the "daytime" or external (surface) horizons of rock formations (of any kind) that have been naturally altered by the combined influence of water, air, and various types of organisms—both living and dead[26] With this Dokuchaev formulated the concept of soil as a fully independent natural-historical body resulting from the interaction of: a) parent material; b) climate; c) plant and animal organisms (biota); d) terrain; and e) the age of the land. His views were expanded by his contemporary and a renowned soil scientist, P.A. Kostychev, who demonstrated that soil formation is a biological process linked to the development of vegetation and microorganisms. Kostychev showed that the stability of soil fertility depends on the balance of organic processes – how plant residues decompose, how microorganisms function, and how plants compete with one another.

V.R. Williams developed the theory of the small biological cycle of substances in the soil that encompassed soil formation, the development of conditions for soil fertility, and the cycling of matter in nature. It clearly demonstrated that, through the appropriate combination of the biological activities of

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травопольных севооборотов, строительства прудов и водоёмов для обеспечения высоких и устойчивых урожаев в степных и лесостепных районах Европейской части СССР. Сборник научных докладов Всероссийской научно-практической конференции, посвященной 125-летию организации «Особой экспедиции лесного департамента по испытанию и учету различных способов и приемов лесного и водного хозяйства в степях южной России, 27 – 28 июня 2017 года. Каменная Степь 2017

[25] FAO 2008. An international technical workshop Investing in sustainable crop intensification The case for improving soil health. Integrated Crop Management Vol.6-2008. FAO, Rome: 22-24 July 2008

[26] В. В. Докучаев. Отчет Нижегородскому губернскому земству. - СПб, 1886. - С. 227

plants, animals, and microorganisms (whether in natural settings or agricultural practice), soil fertility need not be depleted; rather, it can be enhanced.

In short, Dokuchaev defined the soil as a living system, Kostychev showed soil formation as a biological process resulting from the activities of microorganisms and decomposition of plant residues. Williams connected the ideas of Dokuchaev and Kostychev explaining how soil fertility arises and the suitable soil structure that supports soil fertility essential for plant growth and development. As evident, most key scientific principles outlined in FAO's definition of soil health trace their roots to the ideas and concepts developed by Dokuchaev-Kostychev-Williams more than a century ago.

Shelterbelt forest plantation for combating drought and desertification outside the Soviet Union

– U.S. Great Plains Shelterbelt (Dust Bowl response) in the late 1930s
– China's Three-North Shelter Forest Program (also known as the Three-North Shelterbelt Program)
– Africa's Great Green Wall

Sustainable Crop Production Intensification, the Save and Grow model

Many principles and approaches suitable for sustainable crop production intensification outlined in FAO's policymakers guide "Save and Grow" have been developed in the first model of sustainable agriculture, including the following

– enhanced crop nutrition based on healthy soils, through crop rotations and judicious use of organic and inorganic fertilizer
– Integrated water management
– Soil conservation and erosion control
– Integration of crops, pastures, trees and livestock.
– Tree plantation, agroforestry
– Maintenance of soil heath
– Crop rotations
– Conservation of plant genetic resources and their use
– Developing improved and adapted varieties

Ecosystem services

As described in the beginning, V.V. Dokuchaev in his in-depth analysis of natural-climatic changes that occurred in Southern Russia's steppe region over a long period of time showed how forests and natural vegetation regulate moisture, protect crops from winds, storms, and hot dry winds, facilitate the regulation of snow cover and the accumulation of snowdrifts and ridges, stabilize slopes and ravines; grasslands build soils, and rivers sustain hydrological balance. Although framed in the language of forestry, soil science and physical geography rather than ecosystem science, his analysis closely parallels the regulating and supporting ecosystem services recognized today by the FAO.

Conclusion

In this book, we have discussed and demonstrated how the modern concept of sustainable agriculture traces its intellectual roots back to Vasily V. Dokuchaev and his associates, who developed the world's first model of sustainable agriculture almost a century ago. This model stands out from the concept of sustainable agriculture that entered the mainstream international agricultural development thinking in the 1990s with efforts led by FAO in a number of ways. As we have discussed in the beginning, it occurred against the backdrop of the failures and limitations of the Green Revolution – environmental degradation, depletion of soil fertility, overexploitation of groundwater setting stage for aridification and loss of biodiversity being the prominent ones.

But the original one, evolved in the late nineteenth century in Russia, was in response to combat frequent droughts, drywinds, and dust storms that caused massive crop failures resulting in devastating famines. It was focused not on addressing the consequences of such natural disasters but finding solutions that are durable. The conceptual framework was laid out starting from a thorough analysis of the root causes behind these natural disasters. Based on these analyses, the countermeasures were conceived and incorporated in the conceptual framework. It didn't take much time to start field testing of the components of the sustainable agriculture model. Experimental sites were established, where protective forest strips were planted. Beginning in the mid 1930s, sustainable agricultural practices were disseminated to agricultural farms for use in production purposes. In 1948, the Soviet Government took a grandiose project for the transformation of nature by scaling up the sustainable agriculture model on a large geographical scale developed through years of practice at the Kamenno-Stepnaya experimental station and the neighbouring agricultural farms. If the project wasn't terminated by Nikita S. Khrushchev in 1953, sustainable agriculture could be the mainstream of agricultural development in the Soviet Union with global environmental benefits.

Unlike the first sustainable agriculture model, the contemporary sustainable agriculture model pioneered by FAO isn't home-grown. It has been developed by assembling scientific ideas and farming practices that were long known in the developed world and isn't suitable for adoption in the smallholder farming in the developing countries. This is the reason the Sustainable Crop Production Intensification approach elaborated in the "Save and Grow" manual published in 2011 continues to exist mainly as a concept with limited practical use. Meanwhile the Green Revolution, officially declared over, is continuing under different names in many Asian countries.